AN APPARATUS FOR THE DETERMINATION OF OPTIMUMS OF TEMPERATURE AND MOISTURE.

By Thomas J. Headlee,
Manhattan, Kansas.

Pioneer work in economic entomology consisted in the determination of the insect's life history and habits without more than casual regard to the environment in which it lived. From time to time, however, various workers have called attention to the fatal effects of the extremes of temperature and moisture, and a few persons have pursued systematic inquiry into the relations existing between temperature and insect life. Others have used various arthropods in determining the response of protoplasm to various stimuli. The last two types of investigation have proceeded far enough to show that insects in common with other organisms have minimum, optimum and maximum relations to each important stimulus to which they are subjected. More than enough work has been done to show that the life economy of the insect depends to a very large extent directly and indirectly upon the physical, chemical, and animate environment in which it lives, and that no fundamental understanding of its life economy can be reached until the effect of its environment is understood.

While the study necessary to the accumulation of sufficient data to arrive at such an understanding is one requiring much time and expense, certain insects are of such transcendent economic importance that the expenditure of enough time and money to make the most exhaustive study is entirely justifiable. Such insects have as a rule already received pioneer study and a few, owing to their especially marked response to environmental factors, have received more fundamental attention. The writer was first led to see the necessity for making a more fundamental study of highly injurious species by the observation that for certain of the insects most injurious to staple crop production—insects that exact a yearly toll of millions from the state in which he is now located—only inadequate measures of control have been devised, although they have been subjects of study for many years.

In making a study of the relation of environmental factors to the life economy of insects, either the investigator must deal with a sufficiently large number of individuals and instances to

FIG. 1

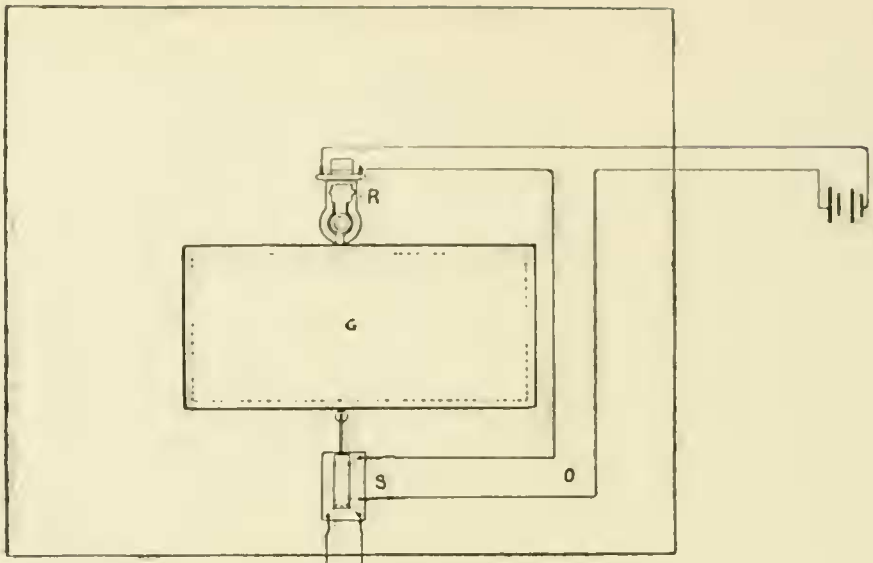
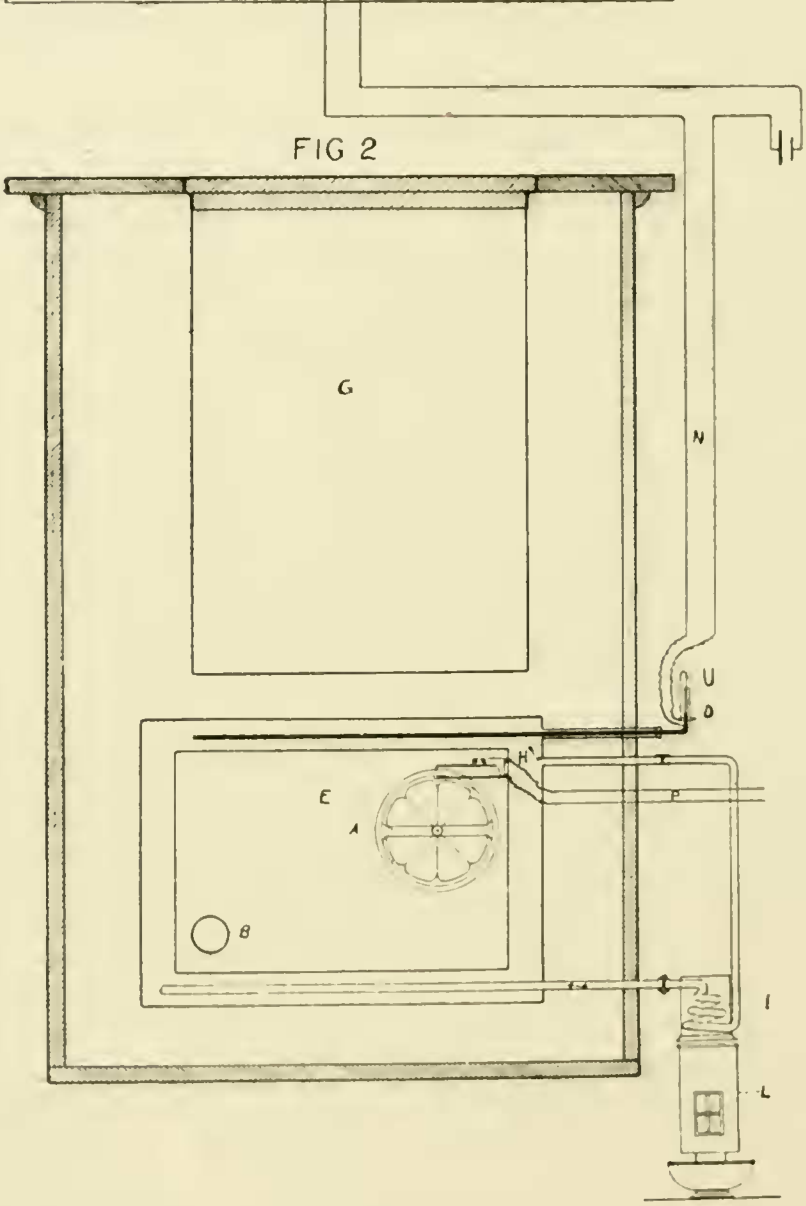


FIG 2



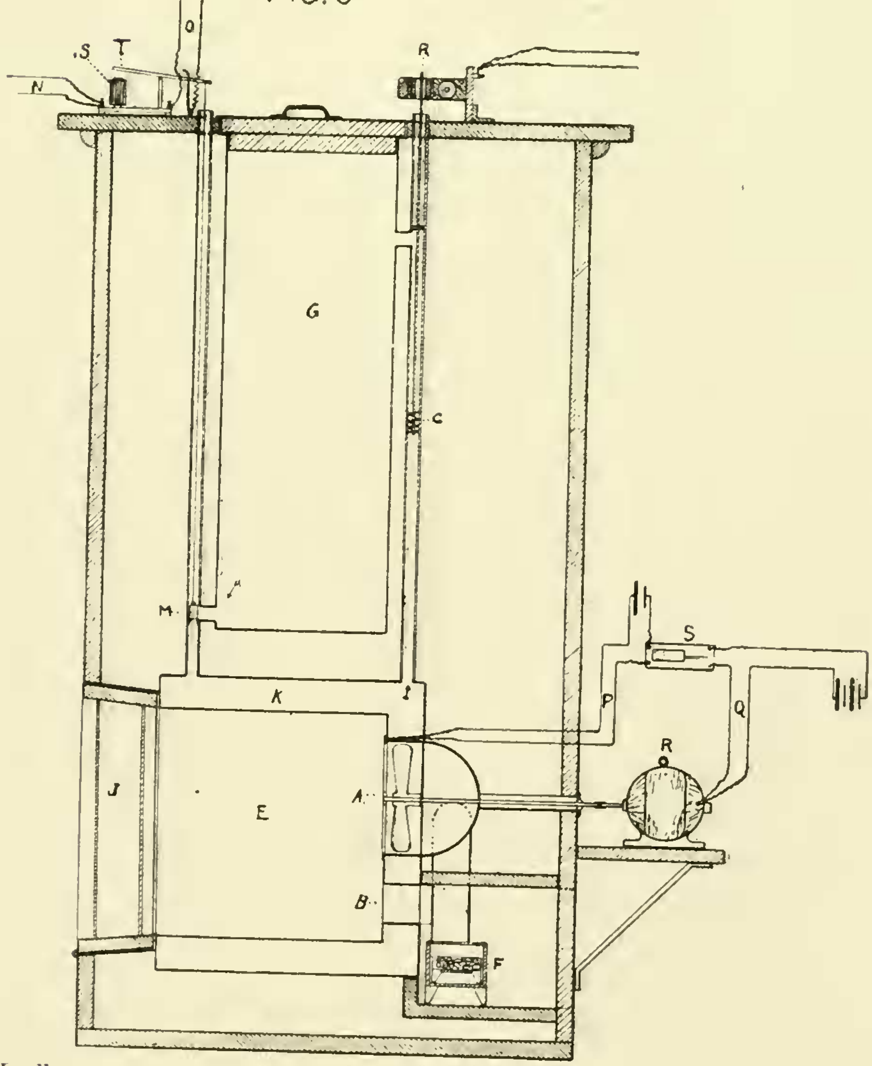
T. J. Headlee.

DIAGRAMATIC VIEW OF CONSTANT TEMPERATURE AND MOISTURE INCUBATOR.

FIG 1 = TOP VIEW
FIG 2 = FRONT VIEW
FIG.3 = SIDE VIEW

A = EXHAUST FAN AND PASSAGE WAY TO LEAD BOX
B = PASSAGE FROM LEAD BOX
C = SPIRAL LIFT
D = THERMOSTAT
E = EXPERIMENT CHAMBER
F = LEAD BOX CONTAINING CALCIUM CHLORIDE
G = ICE CHAMBER
H = HYGROSTAT
I = HEATING COIL
J = GLASS FRONT OF CHAMBER
K = WATER JACKET
L = KEROSENE HEATER
M = VALVE
N = TEMPERATURE-MAGNETIC CIRCUIT
O = " -MOTOR "
P = MOISTURE-MAGNETIC "
Q = " -MOTOR "
R = MOTORS
S = ELECTRO-MAGNETS
T = LEVER U = ELECTRODE

FIG. 3



T. J. Headlee.

reduce the error of the average to a negligible quantity, or he must deal with smaller numbers under conditions in which the important variables are reduced to constants.

In planning a study of the life economy of certain insects most injurious to staple crop production, the writer has adopted the plan of using the smaller number of individuals and of reducing the number of variables to a minimum. Of course it has been easy to eliminate natural enemies and to prevent large variation in the quantity and quality of food supply, but of the physical factors he has thus far been able to reduce only temperature and moisture to constants. This has been accomplished through the construction of an incubator, in which, within limits, desired degrees of each can be maintained.

Construction of the Apparatus. Plates XXI–XXII.

Temperature Phase.

Essentially the incubator consists of a water-jacketed chamber E (figs. 2 and 3) with special provision for heating and cooling the water within the jacket, the whole being surrounded by a box filled with non-conducting packing. The packing used in this instance consisted of wood shavings. The 12″ x 12″ x 18″ chamber is jacketed on three sides only, the fourth being closed by a double glass door for the purpose of admitting light. The water is cooled by the inflow of ice water from tank G (Fig. 3). This exchange is automatically controlled by means of mercurial thermostat D (fig. 2), which projects far into the jacket.

The platinum-tipped electrode U (fig. 2) has been so adjusted that when the temperature of the water within the jacket rises higher than is necessary to bring the air in chamber E (fig. 3) to the desired point, the rising mercury column in D (fig. 2) makes contact with it and completes magnetic circuit N (figs. 2 and 3), magnetizing electromagnet S (fig. 3), pulling lever T (fig. 3) down upon it, thus pulling valve M out of its seat and allowing ice water to flow by gravity into the jacket. The pulling of the lever down on the electromagnet S (fig. 3) completes motor circuit O (figs. 1 and 3), and sets spiral lift C (fig. 3) in motion. This interchange impelled by gravity is thus hastened by pumping. This interchange continues until enough cold water has been introduced into the jacket to cause the mercury column in D (fig. 2) to withdraw from the electrode U (fig. 2). So soon as this happens valve M (fig. 3) falls back into its seat and spiral lift C (fig. 3) stops.

The water within the jacket is heated in coil I (fig. 2) by means of kerosene burner L (fig. 2). The method of heating could be greatly improved where constant electric current is available by the installation of electric heaters under chamber E (fig. 3) and the controlling of the amount of current delivered by some form of thermostat. This portion of the incubator was devised and constructed by the "International Instrument Company," and later so modified by the writer as to fit it for his use.

Moisture Phase.

While certain companies would undertake the construction of constant low temperature incubators, we were unable to obtain a combination constant low temperature and moisture incubator. On the arrival of the constant low temperature incubator, we set about devising a means of bringing the relative humidity under control. After trying many things the writer adopted the method of placing enough plants or water vessels in chamber E (fig. 3) to bring the relative humidity to 100°, then when the relative humidity reached the desired point to prevent its further rise by passing the air over calcium chloride.

An exhaust fan A (figs. 2 and 3) was placed in the rear wall of the chamber E and the air led through a 2½" passageway into a leaden box F (fig. 3) partly filled with calcium chloride, and from there through a similar passageway B (figs. 2 and 3) back into the chamber. The fan, passageways, and leaden box are all included in the packing space of the incubator wall. A strand of human hair, after having the oil removed from it with sulphuric ether, was stretched in an adjustable brass frame. A lever was attached by its short arm to this hair in such a way that variation in the length of the hair strand would cause the distal end of the long arm to move through a considerable space. To this end of this arm was attached a platinum electrode which descended into a mercury-filled tube. Of course, the contact of the platinum point and the mercury was designed to close magnetic circuit P (figs. 2 and 3) and this to close motor circuit Q (fig. 3) which would set the exhaust fan in motion. So long as the platinum point remains in the mercury, the fan continues to change the air. Less than a minute after the connection is made is usually sufficient to dry the air to a point at which the contraction of the hair breaks the connection.

Operation.

In operating the incubator, it is necessary to set the automatic apparatus for both temperature and moisture. The former is accomplished by introducing a standard thermometer into chamber E (fig. 3) and when the rising temperature reaches the desired point, adjusting the electrode so that it almost touches the rising mercury column in D (fig. 2). The latter is accomplished by introducing a standardized hygrograph into chamber E. (Fig. 3) and when the rising relative humidity reaches the desired point, setting the tension of the hair strand so that any further loosening and lengthening will allow the platinum point to make contact with the mercury.

So long, then, as the heat maintains a constantly rising temperature and the ice in the tank is replenished, constant temperature will be maintained in chamber E (fig. 3) and so long as a constantly rising relative humidity is maintained in chamber E (fig. 3), and the calcium chloride is replenished, the constant relative humidity will be maintained.

Its Use Illustrated.*

Inasmuch as the data derived from use of the incubator in the study of *Toxoptera graminum* Rondani are most available, they will be used for illustration.

The determination of the optimum temperature was first attempted. The incubators were so placed that they would get the same quantity and quality of light. The moisture apparatus was set at 75° relative humidity and the temperature apparatus at different temperatures. A considerable number of individual viviparous *Toxoptera graminum* were allowed to complete their life-cycles. The temperature was then changed and the experiment repeated. This process was continued until the effect of temperatures of 50° F., 70° F., 80° F., and 90° F., under constant relative humidity of 75° had been tested.

It is generally accepted that the optimum temperature of an organism is that temperature under which the organism's vital processes are most active.

The temperature under which these insects experienced the lowest mortality and produced the largest number of healthy young in a given time has been considered the optimum tempera-

*The writer desires hereby to acknowledge the aid afforded him by his student assistant, Mr. Francis B. Milliken, who under his immediate direction has tested different plans for the control of moisture and collected data from the insects under observation while the incubators were in operation.

ture. Chart No. 1, curve No. 4 shows that in our tests *Toxoptera graminum* experiences the lowest mortality at 80° F., curve No. 3 shows that the highest daily reproduction is at 80° F., curve No. 1 shows that the shortest time from birth to maturity occurs at 80° F., and curve No. 2 shows that the average period of reproduction is only a little less at 80° F., than at 70° F.

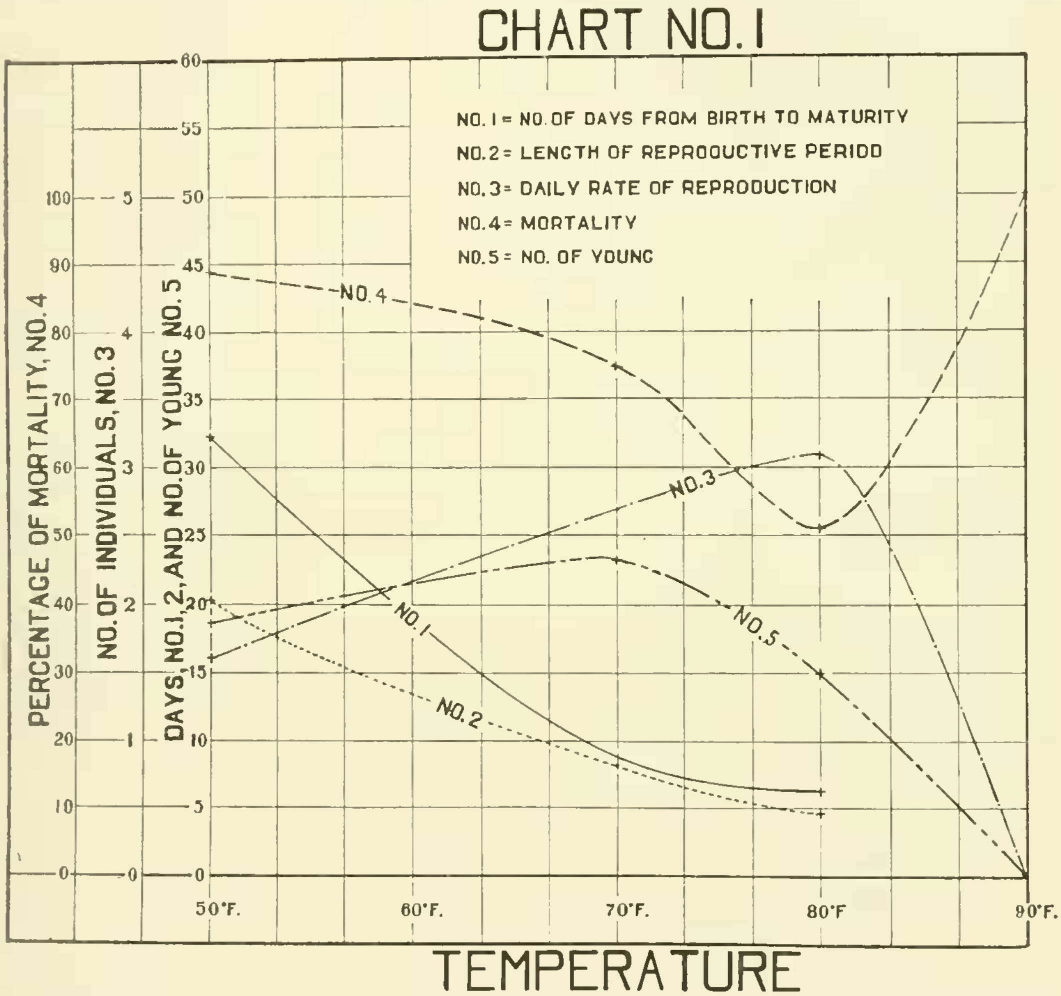


CHART No. 1.—Plotted data showing the relation of *Toxoptera graminum* Rondani to temperature under constant relative humidity of 75°. In curves No. 1 and No. 2, point at 50° F. represent the average of 6 individuals, at 70° F. 27, and at 80° F. 28. In curves No. 3 and No. 5 point at 50° F. represents the average of 6 individuals, at 70° F. 27, at 80° F. 28, and at 90° F. 201. In curve No. 4 point at 50° F. represents the average of 54 individuals, at 70° F. 108, at 80° F. 57, and at 90° F. 201.

Clearly, taking into consideration the effect of higher daily rate and shorter period of immaturity on the geometric rate of increase, *T. graminum* will under constant relative humidity of 75° produce the maximum number of progeny in a given time at 80° F. It is, therefore, reasonable to conclude that the optimum temperature for *T. graminum* under 75° relative humidity is about 80° F., possibly a little above or a little below.